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(54) [Title of the Invention]

MAGNETIC THIN FILM, MANUFACTURING METHOD OF MAGNETIC  
THIN FILM, AND MAGNETIC HEAD

(57) [Abstract]

[Object]

The present invention relates to a magnetic thin film,  
a manufacturing method of the magnetic thin film, and a magnetic

head, and to obtain an FeCo series plating film having high saturation magnetic flux density restrained in generation of pits and cracks without adding nonmagnetic metals.

[Means for Solving]

To include the composition ratio by weight of Fe, Co and Ni in the quadrangle with  $\text{Fe}_{80}\text{Co}_{20}$ ,  $\text{Fe}_{40}\text{Co}_{60}$ ,  $\text{Fe}_{40}\text{Co}_{40}\text{Ni}_{20}$ , and  $\text{Fe}_{70}\text{Co}_{10}\text{Ni}_{20}$  as apexes, and bring the composition ratio of Ni into the range of 1 wt% or more

[Claims]

[Claim 1] A magnetic thin film comprising Fe, Co and Ni, wherein the composition ratio by weight of Fe, Co and Ni is contained in the quadrangle with  $\text{Fe}_{80}\text{Co}_{20}$ ,  $\text{Fe}_{40}\text{Co}_{60}$ ,  $\text{Fe}_{40}\text{Co}_{40}\text{Ni}_{20}$ , and  $\text{Fe}_{70}\text{Co}_{10}\text{Ni}_{20}$  as apexes, and the composition ratio of Ni is 1 wt% or more.

[Claim 2] A manufacturing method of the magnetic thin film as claimed in claim 1 that uses a plating bath, wherein in the plating bath containing Fe ions, Co ions and Ni ions,  $\text{Fe ions}/(\text{Fe ions} + \text{Co ions})$  is  $0.3 \leq \text{Fe ions}/(\text{Fe ions} + \text{Co ions}) < 1.0$ .

[Claim 3] The manufacturing method of the magnetic thin film as claimed in claim 2, wherein an organic unsaturated compound not having a  $[-\text{C}-\text{SO}_2-]$  structure and having a carbon triple bond or a carbon double bond is contained in the plating bath.

[Claim 4] The manufacturing method of the magnetic thin

film as claimed in claim 3, wherein the organic unsaturated compound having a carbon triple bond or a carbon double bond is 2-propyn-1-ol.

[Claim 5] A magnetic head equipped with at least an inductive thin film magnetic head, wherein the magnetic thin film as claimed in claim 1 is used in at least a part of an upper magnetic pole and a lower magnetic pole of the inductive thin film magnetic head.

[Detailed Description of the Invention]

[0001]

[Technical Field to Which the Invention Belongs]

The present invention relates to a magnetic thin film, a manufacturing method of the magnetic thin film, and a magnetic head, in particular relates to a magnetic thin film that is characteristics in constitution for obtaining a plated film of high saturation magnetic flux density  $B_s$  for use in a magnetic device, such as an upper magnetic pole core and thin film transformer for an inductive thin film magnetic head of hard disc drive (HDD), a manufacturing method of the magnetic thin film, and a magnetic head.

[0002]

[Prior Art]

In recent years, the recording density of a hard disc that is an external storage has been improved as high as annual percentage rate, the sizes of magnetic head elements become

smaller, and heightening of the coercive force of a recording medium is advancing, so that a magnetic material having sufficient writing ability to such a recording medium having high coercive force is required.

[0003]

To have sufficient writing ability even to a recording medium having high coercive force, it is necessary to use a material having high saturation magnetic flux density  $B_s$  as an upper magnetic pole core, or an upper magnetic pole core and a lower magnetic pole layer constituting an inductive thin film magnetic head. With requirement for the increment of recording density, it is considered that  $B_s \geq 2.0T$  is essential in future in the part where magnetic fluxes are most concentrated.

[0004]

In addition, since such an inductive thin film magnetic head has a film thickness of a magnetic material of from 3 to 4  $\mu m$  so that sufficient magnetic fluxes are generated at the tip, and has a form having difference in level, the efficiency of film-forming rate is low by vacuum film-forming techniques such as a sputtering method and the like widely used as other methods of deposition of magnetic materials, and further, an effective etching method has not been established. Therefore, magnetic poles are conventionally formed by an electroplating method high in precipitation efficiency and excellent in

selective film formation by using a resist frame.

[0005]

As the material of magnetic poles for writing of conventional inductive thin film magnetic heads, NiFe alloy thin films, i.e., permalloy, is generally used. Incidentally, the saturation magnetic flux density of heretofore widely used  $\text{Ni}_{80}\text{Fe}_{20}$ , i.e., 80NiFe, is  $B_s = 1.0\text{T}$ , and the saturation magnetic flux density of  $\text{Ni}_{50}\text{Fe}_{50}$ , i.e., 50NiFe, is  $B_s = 1.5\text{T}$ .

[0006]

However, NiFe is insufficient for the requirement of the above increment of saturation magnetic flux density, and as the magnetic material responding to the increment of saturation magnetic flux density, an FeCo alloy capable of obtaining the highest saturation magnetic flux density  $B_s$  in magnetic alloys is attracting public attention. Incidentally, in  $\text{Fe}_{60}\text{Co}_{40}$  of bulk,  $2.45\text{T}$  is obtained (if necessary, refer to R.M. Bozorth, IEEE Press, p. 80, 1993).

[0007]

When a magnetic material having such a high composition ratio of Fe is formed as a film, it is necessary to sufficiently raise Fe ion concentration in a plating bath as compared with conventional NiFe and the like, and with the increase in Fe composition ratio, the amount of divalent Fe ions changing to trivalent Fe ions increases.

[0008]

When trivalent Fe ions are present in a plating bath like this, the plated film is generally fragile and liable to be a black-gray plated film having high stress, and further a problem arises such that pits and cracks occur in the plated film, so that the increased amount of trivalent Fe ions in the plating bath cannot be negligible.

[0009]

Accordingly, for solving problem, it is tried to add metal ions of, e.g., Pd, Cu, Pt, Au, Ag, Ir, Rh, Ru and the like to a plating bath containing Fe ions and Co ions (if necessary, refer to JP-A-5-29172 (the term "JP-A" as used herein refers to an "unexamined published Japanese patent application").

[0010]

[Problems that the Invention is to Solve]

However, when metal ions of Pd and Cu are added to a plating bath, since these metals are nonmagnetic metals, there is a problem that saturation magnetic flux density of the obtained plated film lowers.

[0011]

Accordingly, an object of the invention is to provide an FeCo plating film having high saturation magnetic flux density that is restrained in generation of pits and cracks without adding nonmagnetic metals.

[0012]

[Means for Solving the Problems]

The means for solving the problems in the invention will be described with reference to Fig. 1. Fig. 1 is a triangular diagram of composition showing the compositional range of FeCoNi of the invention.

Refer to Fig. 1.

For achieving the above objects, in a magnetic thin film of the invention, the compositional ratio by weight of Fe, Co and Ni is included in the quadrangle with  $\text{Fe}_{80}\text{Co}_{20}$ ,  $\text{Fe}_{40}\text{Co}_{60}$ ,  $\text{Fe}_{40}\text{Co}_{40}\text{Ni}_{20}$ , and  $\text{Fe}_{70}\text{Co}_{10}\text{Ni}_{20}$  as apexes, and the composition ratio of Ni is 1 wt% or more.

[0013]

Ni is small in magnetic moment as compared with Fe or Co but it is a magnetic element different from Pd and Cu, so that it can inhibit the reduction of saturation magnetic flux density  $B_s$  to the least when added as the third element.

[0014]

Further, as apparent from the fact that Ni is widely used as a plating material, Ni is hard, excellent in chemical resistance and a gloss, and capable of obtaining good plating, so that it becomes possible to prevent pits and cracks liable to generate with the increase of the amount of Fe.

[0015]

Accordingly, in an FeCo alloy in which the compositional ratio of Fe is great, by making the compositional ratio of Ni

1 wt% or more, it becomes possible to well reproducibly make a magnetic thin film having small surface roughness  $R_a$ , e.g.,  $R_a < 200$  nm, and high saturation magnetic flux density, e.g.,  $B_s \geq 2.0T$ , and more preferably  $B_s \geq 2.2T$ . The surface roughness  $R_a$  in this case is arithmetic mean roughness provided by the provision of JIS B0601-1994, and taking the surface roughness curve as  $y=f(x)$ , the surface roughness is a value obtained by integrating the absolute value of  $y=f(x)$  covering datum length  $L$ , and normalized by datum length  $L$ . Surface roughness  $R_a$  or roughness  $R_a$  in the specification of the invention means the arithmetic mean roughness provided by the provision of JIS B0601-1994.

[0016]

In this case, as a base layer of plating, it is preferred to use an FeCoNi film that is the same series with the plating film and having saturation magnetic flux density greater than that of NiFe, e.g.,  $Fe_{26}Co_{63}Ni_{11}$ , by which the saturation magnetic flux density of the upper magnetic pole core or the lower magnetic pole layer as a whole can be heightened.

[0017]

Further, the manufacturing method of the magnetic thin film of the invention uses a plating bath containing Fe ions, Co ions and Ni ions, wherein  $Fe\text{ ions}/(Fe\text{ ions} + Co\text{ ions})$  is  $0.3 \leq Fe\text{ ions}/(Fe\text{ ions} + Co\text{ ions}) < 1.0$ .

[0018]

To obtain an FeCo series magnetic thin film having high saturation magnetic flux density like this, it is necessary to make the composition ratio of Fe 0.4 or more, and for that sake it is necessary to make  $\text{Fe ions}/(\text{Fe ions} + \text{Co ions})$  in the plating bath  $0.3 \leq \text{Fe ions}/(\text{Fe ions} + \text{Co ions})$ .

[0019]

In this case, it is desired to contain in the plating bath an organic unsaturated compound not having a  $[\text{=C-SO}_2^-]$  structure and having a carbon triple bond or a carbon double bond, e.g., 2-propyn-1-ol (PPO, molecular formula:  $\text{HC=C-CH}_2\text{-OH}$ ), by which it is possible to form a plated film having small surface roughness  $R_a$ .

[0020]

Further, in the invention, in a magnetic head equipped with at least an inductive thin film magnetic head, the above magnetic thin film is used in at least a part of the upper magnetic pole and the lower magnetic pole of the inductive thin film magnetic head.

[0021]

By using the magnetic thin film in this manner, the performance of the magnetic head heightens and manufacturing costs can be reduced, in addition, it becomes possible to improve the performance of a magnetic storage. Incidentally, in this case, the entire of the upper magnetic pole and the lower magnetic pole may be constituted of the magnetic thin

film, or either of them may be constituted of the magnetic thin film, or may be used at least as the chip-like magnetic core at the tip part of the upper magnetic pole and the lower magnetic pole.

[Mode for Carrying Out the Invention]

[0022]

The manufacturing method of the magnetic thin film in the embodiments of the invention will be described with reference to Figs. 2 to 6. As a plating apparatus for use in the embodiments of the invention, a paddle apparatus usually used as prior art is used, and electrolytic plating is carried out while stirring the plating bath by the paddle apparatus, and the form of the paddle, the distance to the substrate on which a magnetic thin film is deposited, i.e., the distance to the cathode, and the rotation speed are arbitrarily set and not especially restricted.

[0023]

Further, in the plating apparatus for use in the embodiments of the invention, ferrous sulfate ( $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ ), nickel sulfate ( $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$ ), and cobalt sulfate ( $\text{CoSO}_4 \cdot 7\text{H}_2\text{O}$ ) are mixed so that metallic ion concentration in the plating bath of  $\text{Fe}^{2+}:\text{Co}^{2+}$  is from 30:70 to 100:0, and  $\text{Ni}^{2+}:(\text{Fe}^{2+}+\text{Co}^{2+}+\text{Ni}^{2+})$  is from 0.01:100 to 80:100, 30 g/liter of boric acid is added to thereby adjust pH to 2.0 to 3.5, e.g., 2.5, conductivity is adjusted with ammonium chloride, and further 0.2 g/liter

of sodium dodecylbenzenesulfonate as a surfactant is added. Further, ascorbic acid is added as an antioxidant.

[0024]

Electrolytic plating is performed with such a plating bath. An Si substrate on the surface of which an  $\text{SiO}_2$  film is formed is used as the substrate, and for improving adhesion, a Ti film having a thickness of 10 nm is formed by sputtering, and then an FeCoNi film having a thickness of 50 nm is formed by sputtering as the plating base layer. Incidentally, the composition ratio of the FeCoNi film by weight is  $\text{Fe}_{26}\text{Co}_{63}\text{Ni}_{11}$ .

[0025]

In the next place, electrolytic plating is performed at from room temperature to 40°C, e.g., at 30°C, with a plurality of electric current densities between 5 and 20 mA/cm<sup>2</sup>, and direct current magnetic field of 400 (Oe) or more, e.g., 400 (Oe), thus an FeCoNi magnetic thin film is formed on the FeCoNi base layer.

[0026]

Refer to Fig. 2.

Fig. 2 is a drawing explaining the dependency on Ni composition ratio of the film-forming rate of the plated film, and in this case, the film-forming rate is examined by changing  $\text{Ni}^{2+}$  concentration while maintaining the ratio of  $\text{Fe}^{2+}:\text{Co}^{2+}$  in the plating bath at 50:50, and the Ni composition ratio in the Figure shows the weight ratio of Ni in the plated film.

[0027]

As is apparent from the drawing, it is understood that the film-forming rate increases with the increase of Ni composition ratio, and film forming was substantially impossible when Ni ions were not contained in the plating bath. The reason for this is presumed that Ni itself has catalytic function, and by the fact that Ni ions are contained in the plating bath, Ni itself is liable to precipitate and at the same time accelerates the plating reaction. By 1.0 wt% of Ni composition ratio to the weight of the plated film, a film-forming rate of 0.05  $\mu\text{m}/\text{minute}$  was obtained.

[0028]

Refer to Fig. 3.

Fig. 3 is a drawing explaining the dependency on Ni composition ratio of the surface roughness  $R_a$  of the plated film on the same film-forming condition as in the case of Fig. 2. As is apparent from the Figure, it is understood that the surface roughness  $R_a$  becomes small with the increase in Ni composition ratio.

[0029]

This is presumably due to the fact that Ni is excellent in a gloss by nature and provides a good plated film, so that pits that are liable to occur with the increase of Fe restrained the generation of cracks. Incidentally, when Ni composition ratio is 1.0 wt% to the weight of the plated film,  $R_a$  is about

200 nm, and when 5 wt% or more,  $R_a$  is about 10 nm or so.

[0030]

Refer to Fig. 4.

Fig. 4 is a drawing explaining the dependency on Ni composition ratio of the saturation magnetic flux density  $B_s$  of the plated film on the same film-forming condition as in the case of Fig. 2. As is apparent from the Figure, it is understood that the saturation magnetic flux density  $B_s$  lowers with the increase in Ni composition ratio. Incidentally, white circle in the Figure is the value in literature in the case of Ni is 0 wt% (if necessary, refer to R.M. Bozorth, IEEE Press, p. 80, 1993), and  $B_s$  is about 2.4T.

[0031]

This is for the reason that although Ni is a magnetic element, small in magnetic moment as compared with Fe or Co. Therefore, saturation magnetic flux density  $B_s$  lowers with the increase in Ni composition ratio, but as compared with the case where nonmagnetic elements such as Pd and Cu are added, the reduction of saturation magnetic flux density  $B_s$  can be restrained. Incidentally,  $B_s$  is about 2.0T with Ni of about 20 wt%, and saturation magnetic flux density  $B_s$  of about 2.2T can be maintained until Ni composition ratio reaches 15 wt%, although measurement error is present.

[0032]

Refer to Fig. 5.

Fig. 5 is a drawing of measurement of the precipitation amount of Ni (wt%) in the plated film by changing  $\text{Ni}^{2+}$  concentration, i.e.,  $\text{NiSO}_4$  concentration, while maintaining the ratio of  $\text{Fe}^{2+}:\text{Co}^{2+}$  in the plating bath at 50:50 similarly to the case in Fig. 2, and the  $\text{Ni}^{2+}$  concentration is shown in molar ratio of  $\text{NiSO}_4/(\text{FeSO}_4+\text{CoSO}_4+\text{NiSO}_4)$ .

[0033]

As shown above, film forming is impossible when  $\text{NiSO}_4$  is not added to the plating bath, but as is apparent from the Figure, when  $\text{NiSO}_4$  is added so that  $\text{NiSO}_4/(\text{FeSO}_4+\text{CoSO}_4+\text{NiSO}_4)$  is 0.01 mol%, it is understood that the precipitation amount of Ni is about 1.0 wt%.

[0034]

Refer to Fig. 6.

Fig. 6 is a drawing showing the dependency on concentration ratio of  $\text{FeSO}_4$  and  $\text{CoSO}_4$  of the precipitation amount ratio of Fe and Co, and the precipitation amount ratio of Fe and Co in the plated film was examined by changing the ratio of  $\text{FeSO}_4/\text{CoSO}_4$  while maintaining the concentration of  $\text{NiSO}_4$  in the plating bath at 0.01 mol%. The concentration ratio in the plating bath of  $\text{FeSO}_4/(\text{FeSO}_4+\text{CoSO}_4)$  is shown in mol%, and the precipitation amount ratio of  $\text{Fe}/(\text{Fe}+\text{Co})$  is shown in wt%.

[0035]

As is apparent from the Figure, it is understood that

with the increase of  $\text{FeSO}_4 / (\text{FeSO}_4 + \text{CoSO}_4)$ ,  $\text{Fe}/(\text{Fe}+\text{Co})$  increases almost linearly, and by extrapolation of the inclination, the least upper bound of Fe composition ratio is 80%.

[0036]

On the other hand, the greatest lower bound of Fe composition ratio is not present from the film-forming conditions, but since Fe composition ratio is elevated to obtain a magnetic film having high saturation magnetic flux density, it is preferred that Fe composition ratio is 40% or more, and especially preferably 50% or more. Incidentally, for making Fe composition ratio 40% or more, referring to Fig. 6, it is understood that  $\text{FeSO}_4 / (\text{FeSO}_4 + \text{CoSO}_4)$  is necessary to be 30 mol% or more, although measurement error is present.

[0037]

Synthetically considering the above collectively, since a film-forming rate can be increased and surface roughness  $R_a$  can be lessened by the addition of Ni to an FeCo series plating bath, the Ni composition ratio in a plated film is preferably 1.0 wt% or more, more preferably 2.0 wt% or more, and for obtaining excellent characteristics in connection with the film forming rate, surface roughness  $R_a$ , and saturation magnetic flux density  $B_s$  as a whole, the Ni composition ratio is preferably 5.0 wt% or more.

[0038]

On the other hand, as is apparent from Fig. 4, for

achieving high saturation magnetic flux density, Ni composition ratio is preferably smaller, and when the object of obtaining a film having high saturation magnetic flux density of  $B_s \geq 2.0T$  or from the first is taken into consideration, it is preferred that Ni composition ratio is 20 wt% or less, and to achieve  $B_s$  of about 2.2T, 15 wt% or less is preferred.

[0039]

Further, as is apparent from Fig. 6, Fe/(Fe+Co) is also restricted, and the composition ratio of Fe is preferably from 40 to 80 wt% as above.

[0040]

Refer to Fig. 1 again.

Fig. 1 shows the preferred range of the composition collected the above, and it is understood that the range in which the composition ratio is contained in the quadrangle with  $\text{Fe}_{80}\text{Co}_{20}$ ,  $\text{Fe}_{40}\text{Co}_{60}$ ,  $\text{Fe}_{40}\text{Co}_{40}\text{Ni}_{20}$ , and  $\text{Fe}_{70}\text{Co}_{10}\text{Ni}_{20}$  as apexes, and the composition ratio of Ni is 1 wt% or more is preferred.

[0041]

Accordingly, by using the magnetic thin film that satisfies the above conditions at least as a part of an inductive thin film magnetic head, recording on a magnetic recording medium having high coercive force becomes possible. For example, in a U-shaped inductive thin film magnetic head where upper and lower magnetic pole layers are bonded at the

center of the light coil may have the structure, the magnetic head may comprise two layer structure in which the inside layer is composed of the magnetic thin film of the invention, or in the case of tipped type magnetic pole, where narrow protrusions to reduce the core width are provided at the tips of the upper and lower magnetic pole layers, that is, opposed to each other up and down at light pole, the protrusions may be constituted of the magnetic thin film of the invention, by which recording on a magnetic recording medium having high coercive force becomes possible and the improvement of recording density can be achieved.

[0042]

The embodiments of the invention have been described, but the invention is not restricted to the constitutions described in the embodiments, and various modifications can be made. For example, in the above embodiments, ammonium chloride is used as the reagent to heighten the conductivity of the plating bath, but the reagent is not restricted to ammonium chloride and, for example, sodium chloride or ammonium sulfate may be added.

[0043]

Further, in the above embodiments, the plating bath not containing an organic additive, e.g., sodium saccharin, i.e., a primary gloss agent is used, but for reducing surface roughness  $R_a$ , an organic additive, e.g., sodium saccharin may

be added.

[0044]

Incidentally, the primary gloss agent in Ni plating does not exhibit a gloss by itself alone or shows semi-gloss at most, but reveals excellent gloss when used in combination with the later-described secondary gloss agent, moreover, the primary gloss agent has the effect to lower the inside stress given by the secondary gloss agent. In general, sulfur compounds having a double bond, such as  $[C=C-SO_2]$  and  $[C=C-C-SO_2]$  are widely used, e.g., sodium 1,3,6-naphthalenetrisulfonate corresponds to the primary gloss agent.

[0045]

Further, as another method to reduce surface roughness  $R_a$ , organic unsaturated compounds that are organic additives not having a structure of  $[=C-SO_2-]$ , and having either a carbon triple bond or a carbon double bond, i.e., the secondary gloss agent may be used. By the addition of such organic unsaturated compounds, not only surface roughness  $R_a$  can be reduced, but also a magnetic thin film excellent in corrosion resistance can be obtained.

[0046]

As the organic additive, as the secondary gloss agent not having a structure of  $[=C-SO_2-]$  and having a carbon triple bond  $[C=C]$ , 2-propyn-1-ol (PPO, molecular formula:  $HC=C-CH_2-OH$ ) is preferred, but the organic additive is not

restricted to 2-propyn-1-ol, and a secondary gloss agent not having a structure of [=C-SO<sub>2</sub>-] and having a carbon triple bond [C=C] similarly to 2-propyn-1-ol, e.g., 2-butyn-1-ol or 2-butyne-1,4-diol may be used.

[0047]

Further, a secondary gloss agent not having a structure of [=C-SO<sub>2</sub>-] and having a carbon double bond (C=C), e.g., sulfonbenzaldehyde and coumarin derivatives may be used.

[0048]

In the above embodiments, ascorbic acid is added to the plating bath as the antioxidant, but the film-forming rate of a plated film is liable to lower when ascorbic acid is added, so that it may not always be added.

[0049]

Further, in the above embodiments, the FeCoNi film of the same series with the plated film is used as the plating base layer for heightening saturation magnetic flux density, but the plating base layer is not restricted to the FeCoNi film, and an NiFe film may be used.

[0050]

Further, in the explanation of the above embodiments, the magnetic thin film is explained supposing to be used in the upper magnetic pole layer or lower magnetic pole layer of an inductive thin film magnetic head, but the use of the invention is not restricted thereto, and may be used as the

upper and lower magnetic shield layers of a single MR head for reproduction only, or may be used as the upper and lower magnetic shield layers and upper and lower magnetic pole layers as a whole or as a part of a composite thin film magnetic head comprising lamination of an inductive thin film magnetic head and an MR head.

[0051]

Further, the invention is not restricted to the magnetic materials for use in a magnetic head, and, for example, the invention can be used a magnetic shield material or a magnetic transformer in magnetic measuring apparatus and the like.

[0052]

The characteristics of the invention are described in detail below.

(Additional remark 1)

A magnetic thin film comprising Fe, Co and Ni, wherein the composition ratio by weight of Fe, Co and Ni is contained in the quadrangle with  $Fe_{80}Co_{20}$ ,  $Fe_{40}Co_{60}$ ,  $Fe_{40}Co_{40}Ni_{20}$ , and  $Fe_{70}Co_{10}Ni_{20}$  as apexes, and the composition ratio of Ni is 1 wt% or more.

(Additional remark 2)

The magnetic thin film as described in additional remark 1, wherein the saturation magnetic flux density of the magnetic thin film is 2.0T or more.

(Additional remark 3)

The magnetic thin film as described in additional remark 1 or 2, wherein an FeCoNi film is used as the plating base layer of the magnetic thin film.

(Additional remark 4)

A manufacturing method of the magnetic thin film as described in additional remark 1 that uses a plating bath, wherein in the plating bath containing Fe ions, Co ions and Ni ions,  $\text{Fe ions}/(\text{Fe ions} + \text{Co ions})$  is  $0.3 \leq \text{Fe ions}/(\text{Fe ions} + \text{Co ions}) < 1.0$ .

(Additional remark 5)

The manufacturing method of the magnetic thin film as described in additional remark 4, wherein the Ni ion concentration in the plating bath is 0.01% or more to the concentration of all the metal ions.

(Additional remark 6)

The manufacturing method of the magnetic thin film as described in additional remark 4 or 5, wherein an organic unsaturated compound not having a  $[\text{C}-\text{SO}_2-]$  structure and having a carbon triple bond or a carbon double bond is contained in the plating bath.

(Additional remark 7)

The manufacturing method of the magnetic thin film as described in additional remark 6, wherein the organic unsaturated compound having a carbon triple bond or a carbon double bond is 2-propyn-1-ol.

(Additional remark 8)

A magnetic head equipped with at least an inductive thin film magnetic head, wherein the magnetic thin film as described in any of additional remarks 1 to 3 is used in at least a part of an upper magnetic pole and a lower magnetic pole of the inductive thin film magnetic head.

(Additional remark 9)

A magnetic storage equipped with the magnetic head as described in additional remark 8.

[0053]

[Advantage of the Invention]

According to the invention, a good plating film that is restrained in the reduction of saturation magnetic flux density to the least and free from pits and cracks can be obtained by the addition of Ni ions to the plating bath in forming a magnetic thin film having a high Fe composition ratio and high saturation magnetic flux density, which contributes to the increase of frequency of a thin film magnetic head and the improvement of recording density, and further greatly contributes to the spread of a magnetic storage and the like having built-in high performance HDD apparatus, etc.

[Brief Description of the Drawings]

Fig. 1 is a drawing explaining the preferred range of the composition ratio of the magnetic thin film in the embodiment of the invention.

Fig. 2 is a drawing explaining the dependency on Ni composition ratio of the film-forming rate of the plated film in the embodiment of the invention.

Fig. 3 is a drawing explaining the dependency on Ni composition ratio of the surface roughness  $R_a$  of the plated film in the embodiment of the invention.

Fig. 4 is a drawing explaining the dependency on Ni composition ratio of the saturation magnetic flux density  $B_s$  of the plated film in the embodiment of the invention.

Fig. 5 is a drawing explaining the dependency on  $\text{NiSO}_4$  content of the precipitation amount of Ni in the embodiment of the invention.

Fig. 6 is a drawing explaining the dependency on concentration ratio of  $\text{FeSO}_4$  and  $\text{CoSO}_4$  of the precipitation amount ratio of Fe and Co in the embodiment of the invention.